BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 02007

SUBJECT: Effects of Apollo Program Experience on the Design of the AAP Cluster Water Management System
Case 620

DATE: February 4, 1970

FROM: J. J. Sakolosky

ABSTRACT

The water management systems of the Apollo Program's Command Module and Lunar Module have experienced numerous minor failures and deviations from desirable system performance. Some examples are the pre-flight loading of contaminated water into potable storage tanks, corrosion of the CM system by chlorine, leakage and spillage from the chlorine injection system in the CM, incomplete mixing of chlorine in the CM system, cross-contamination between the waste water storage tank and the potable storage tank in both the CM and LM, and iodine depletion in the LM tanks. The design of the water management system for the AAP Cluster has been accomplished keeping these problems in mind. In particular, an all stainless steel system has been adopted for the SWS in an effort to eliminate corrosion. No water line connections exist between any of the water storage tanks, and thorough pre-flight sterilization techniques will be employed. Iodine has been chosen as the bactericide for the AAP Cluster.

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MEMORANDUM FOR FILE

The Apollo Program has experienced continuing difficulties in the operation of the potable water supply systems in the CM and the LM. Some of these problems have yielded to "quick fixes" and been eliminated after the early flights; other problems, though, are due to material incompatibilities and system design and have not been eliminated during the program. Because of the limited mission durations (two weeks) involved, the Apollo Program has been able to live with these problems and has accepted the penalties of minor crew inconvenience and aggravation imposed by the water system. For mission durations of the length planned for the AAP, however, problems of this same nature would be unacceptable for several reasons. Most importantly, the medical aspects of ingesting (over long durations) water which does not meet the rigid chemical, physical, and microbial criteria imposed for space flight are not known. Secondly, for two month missions, a water supply with disagreeable taste or smell would most likely be considered by the crew to be more than a minor inconvenience, particularly when that same water supply is used for food reconstitution. An unappetizing water supply could significantly alter the amount of water consumed by the crew in their daily activities. The purpose of this memorandum will be to review the problems that the Apollo Program has experienced with the potable water supply systems of the CM and LM. The AAP water storage system will then be discussed, and measures taken in the design of the AAP system to avoid the same problems that have plagued the Apollo Program will be described.

Problems Experienced in the CM and LM Potable Water Systems

Potable water in the CM is loaded into the potable storage tank prior to launch and replenished by water produced by the fuel cells. Microbial control of the system is maintained by the intermittent injection of chlorine into the line running from the fuel cells to the potable water tank. The need for chlorination derives from the fact that a path exists between the waste water storage tank (which is used to store water condensed in the suit loop heat exchangers and thus has an inherent microorganism content) and the potable water storage tank. Check valves are used in the connecting lines to prevent the flow of water from the waste tank to the potable tank; they perform this job admirably, but they cannot prevent the migration of microorganisms from the waste to the potable tank. Microorganisms have also been introduced into the potable water supply through the water dispenser gun. It is suspected that microorganisms migrate from the nozzle upstream to the potable storage tank. In addition to these in-orbit contamination sources, inadequate pre-flight loading techniques have in some instances resulted in initial contamination of the potable tank.

The intermittent injection of chlorine into the system has caused a number of difficulties - perhaps more than it has solved. Instances of spillage and leakage from the injector have occurred. Being extremely toxic and reactive with both metals and non-metals, any large amounts of spillage or leakage could have serious harmful effects on both crew and spacecraft. After injection of the chlorine into the system, a period of time must be allowed for the chlorine to mix thoroughly before the water can be ingested. Positive mixing of the chlorine in zero-g has been a problem, and instances have occurred when the chlorine concentration has been so great as to discourage even the thirstiest of crewmen.

Much of the Apollo water system is made of aluminum. Chlorine in the system reacts with the aluminum, resulting in corrosion and pitting. Also, heavy metals (Iron, Nickel, Copper, Chromium) have been found in tests made of the potable water system. High concentrations of these metals may have injurious, or at least unknown, effects on the human system. It is conjectured that these metals may have been replaced by chlorine in the brazed joints and other portions of the system.

Finally, the CM experienced the problem of H_2 gas entrainment in the potable water system. This resulted from an incomplete phase separation at the fuel cells during the early flights. The problem was solved for the latter Apollo flights.

Potable water consumed in the LM is supplied from one of two ascent stage tanks or a descent stage tank. The tanks are pre-loaded before launch. Iodine is used as the bactericide in the LM tanks. The tanks are pre-charged to an initial concentration of iodine prior to launch; no provision exists for the injection of iodine into the system during the mission.

The LM potable water system has not been subject to the large variety of problems that has affected the CM. A problem common to both systems, though, is the cross-contamination resulting from a connection between the waste water system and the potable system. Like the CM, the LM has been subjected to pre-flight loading contamination problems. A problem unique to the LM water system has been the gradual decrease in the initial concentration of iodine in the tanks. This has been attributed to the absorption of iodine by a silicone rubber bladder in the tanks. Some evidence exists that the iodine is actually permeating the bladder and forming crystals on the air side. A gas side transducer used for measuring the quantity of water in the LM tank was found to become excessively corroded (presumably from contact with iodine) during ground tests and was eventually removed from the system. The bladder is also permeable to air. This allows the pressurant gas to become entrained in the potable water.

Description of the AAP Water Management System

Water for the first three AAP missions is stored in 10 cylindrical tanks mounted circumferentially toward the forward end of the SWS. (See Figure 1). Each tank is capable of holding 621 pounds of useable water, allowing a total system capacity in excess of 6200 pounds. The tanks are made of stainless steel and contain a stainless steel bellows which is driven by oxygen pressure to force the water from the tank. The only interconnection between the tanks is through the oxygen pressurization line as illustrated in Figure 1. No water line connections exist between any of the tanks.

Water is utilized by the crew in the Head and the Wardroom of the crew quarters. A combination of hard-line and flex-line plumbing connects the water systems of the Head and Wardroom to separate water storage tanks. This is shown schematically in Figure 1 and Figure 2. The hard-line plumbing, fittings, water chiller and heater tanks, and the Cluster portable water tank are all made of stainless steel. The connection from the hard-line plumbing (from either the Head or the Wardroom) to a water storage tank is made at the tank by means of a flexible supply line. This line will be made of either a flourel or teflon liner covered by a metal braid. Six of the storage tanks will supply water only to the Wardroom. Two of the remaining tanks will supply water only to the Head. The remaining two tanks (designated as contingency tanks) can supply water to either the Head or the Wardroom, but only one at a time. The length of the flexible supply lines determines which tanks can be used for only the Head or only the Wardroom and which tanks are the contingency tanks. When the water in a tank has been depleted, the connection at the tank will be broken, and the flexible supply line will be manually connected to the next tank.

Iodine is used as the bactericide for the AAP Cluster water management system. Provision is made for the injection of a concentrated solution of iodine into each of the 10 water storage tanks when deemed necessary. A stainless steel tank is used to store the concentrated iodine solution. Iodine concentration in the system may be determined by use of the biocide monitoring and injecting equipment. This system exposes a starch solution to a sample of water from the potable system. Starch, when exposed to iodine, turns a characteristic blue color - the deepness of the blue depending on the concentration of iodine. A color chart comparator is provided which allows the concentration of iodine in the water to be determined.

Discussion

The design of the water management system for the AAP Cluster substantially reflects the experience gained during the Apollo Program. A considerable effort is being made to avoid the problems encountered by the water systems of the CM and the LM.

No water connections exist between any of the Cluster water storage tanks. Waste water (i.e. condensate) is collected in a tank in the Airlock Module and then dumped overboard into the LOX tank. This, along with the technique of sequentially connecting a flexible supply line to only the tank in use, eliminates the possibility of cross-contamination of the potable water supply.

It is expected that the chlorine corrosion problem encountered by the CM will be avoided in the AAP Cluster by going to an all stainless steel system with an iodine biocide. An all stainless steel system should also eliminate the appearance of heavy metals in the water supply. The stainless steel bellows in the water tanks will eliminate the iodine depletion problem associated with the silicone rubber in the LM tanks. Unlike the CM system which had chlorine added into a line upstream of the potable tank, the iodine biocide will be injected directly into the water storage tanks in the SWS. The mixing characteristics of the iodine and water in a zero-g environment is a question that remains open to speculation.

The pre-flight water loading techniques to be used in AAP will also benefit from the experience accumulated during the Apollo Program. The storage tanks and plumbing will be subjected to a steam sterilization process prior to launch. In addition, the plumbing and water gun dispensers will be subjected to a concentrated iodine soak while still on the ground. Prior to leaving the Cluster at the end of a mission, the crew will disconnect the Head and the Wardroom flexible supply lines from their respective storage tanks, and the entire system downstream of the tank will be evacuated to space vacuum by means of a line to the LOX tank. Upon revisit, the system plumbing and dispensers will be subjected to an iodine soak prior to system activation.

It is anticipated that some difficulties will be encountered in using the biocide monitoring equipment when the concentration of iodine is below 3 ppm. Apparently, the system as presently conceived cannot distinguish between low iodine concentrations. Alternate biocide monitoring techniques are under investigation.

Acknowledgment

The information on the problems experienced by the Command Module and Lunar Module water management systems was compiled by the joint effort of E. J. McLaughlin (MMS), R. M. Farrell (MMS), and the author.

J.J. Sakolosky

1022-JJS-mef J. J. Sakolosky

Attachments
Figures 1-2

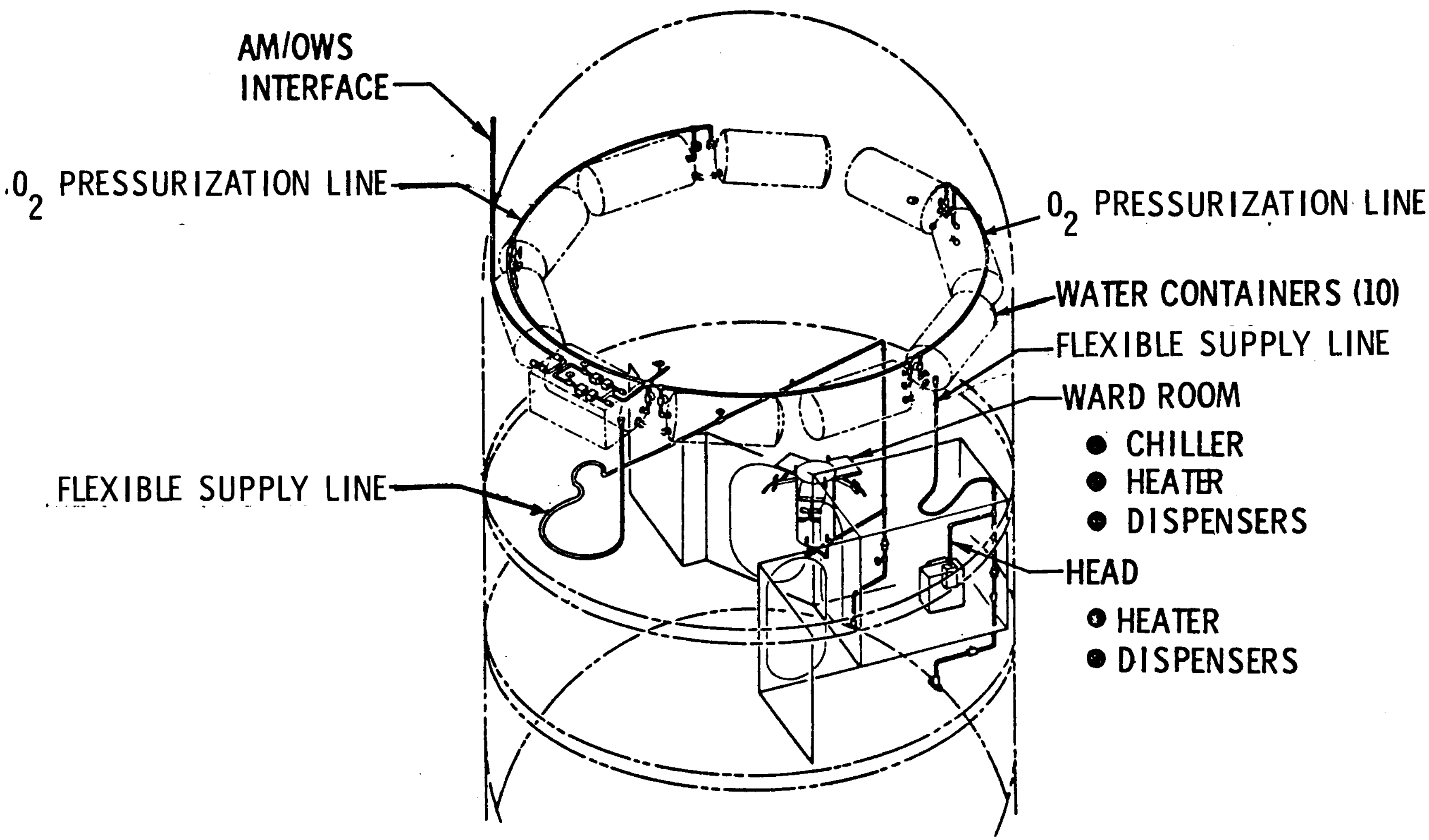

FIGURE 1 - DRY WORKSHOP WATER STORAGE TANKS AND SYSTEM PLUMBING

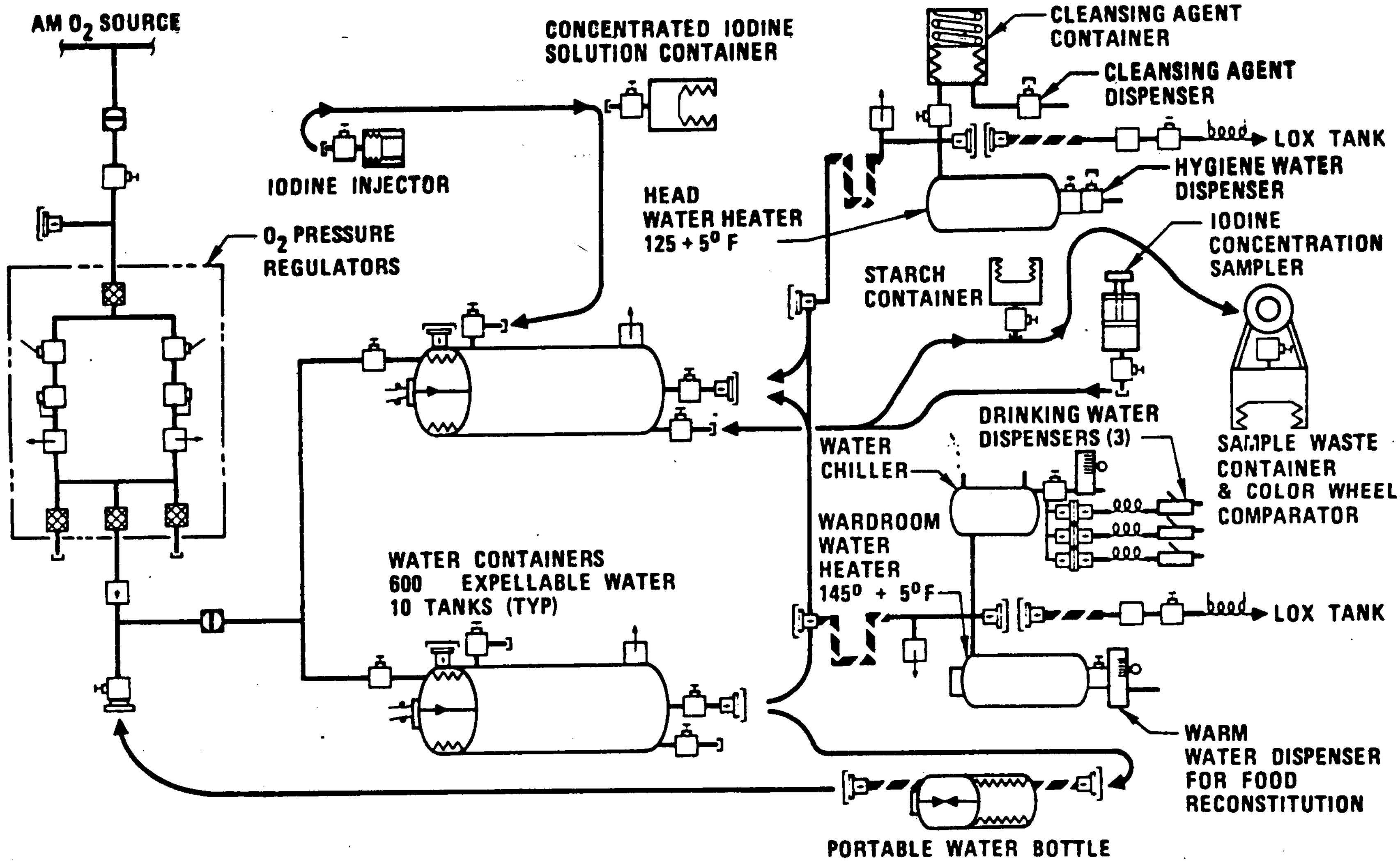

FIGURE 2 - DRY WORKSHOP WATER SYSTEM SCHEMATIC

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